

or mention of a Bishop Mamertus, or of some intrusive bishop who may have been Mamertus? Labbe's "Sacrosancta Concilia" (at the British Museum or the London Library) might be consulted to see whether any hint is given of Mamertus having been in Italy, either in the letters of Leo, or (more probably) in those of his successor, Hilary (iv. pp. 1032—1047).

Procopius got his information during the first Gothic war (A.D. 535—540); the second lasted from A.D. 544 to A.D. 548. He died about A.D. 565, at the age of 60. Ought the "century or more ago" to be computed from the date of his information, or from the time when he wrote? This might make a difference of 10 or 20 years. If the former, then the commencement (?) and violence of the eruptions are thrown back to the early part of the fifth century. In any case they must have preceded rather than followed the interval from 455 to 463. Where did Prof. Daubeny get his date of A.D. 472? Certainly not here.

It is therefore very likely that about A.D. 455 Vesuvius may have been in a state of violent activity. In that year Rome was sacked. These are precisely the conditions which the hypothesis requires. Procopius was told that the Rogations were occasioned by such eruptions at about that date. If, then, Mamertus was the sole (?) author of them, he must have been present where the Terrors occurred. Is there positive evidence of the fact? If no positive evidence, for or against, can be found, it will then be time enough to go into other questions of probability. Here for the present I conclude.

HENRY NORTON

WATER ANALYSIS

II.

IN the last article* we assumed that the object of estimating the organic carbon and nitrogen has been fully understood by the reader; but in order to render all chance of our meaning being misunderstood in the remarks which are to follow, it will be as well to briefly recapitulate the reasons which render these determinations so valuable. Carbon and nitrogen form with hydrogen the principal constituents of all organised bodies, and hence are found in all the excreta of animals. Nitrogen is found in animals to a much greater extent than in plants, while in the inorganic world this latter element is scarcely found at all, and carbon only in the form of carbon, coal or carbonic acid, none of which bodies are likely to be found in water except the last, the first two being insoluble. It hence follows that if a large quantity, or indeed any quantity, of carbon and nitrogen be found in water, their source can only have been organic in its nature, and if the proportion of nitrogen to carbon be more than one to five, the source is almost absolutely certain to have been animal.

Accordingly, when we find these two elements existing in waters in the proportions just indicated, we are justified in assuming the presence of some form of animal or organic contamination in them; and of all forms in which this contamination can exist, sewage is the most probable. It will thus be seen that when chemists assert that a water is contaminated with sewage, they do so on grounds the truth of which is easily demonstrable. That such waters containing effete animal matters are injurious, no arguments of ours will be required to prove; no persons of authority in sanitary matters have presumed to assert that such waters are harmless.

With regard to the method of obtaining evidence as to this contamination, however, considerable difference of opinion exists, and in the former paper we have endeavoured to show the worthlessness of the early processes of estimating organic matter by ignition of the residue,

and by treatment with permanganate of potash; and though this last process is condemned by all, it is still in use.

We have also given reasons for regarding with distrust the results obtained by the use of Chapman, Wanklyn, and Smith's method of indirect determination of organic matter from the amount of ammonia evolved by the water, as we maintain that it cannot be shown that the ammonia evolved bears any distinct relation to the amount of organic matter present, and that with many waters it is difficult to obtain an accurate estimate of the ammonia thus evolved.

The process we have now to consider bases its claims to confidence on the fact that it gives an absolute determination of the quantity of carbon and nitrogen present in the water, and that it does do this can, we think, be proved without much difficulty.

The process is based upon the fact that when a body containing carbon and nitrogen is heated in contact with cupric oxide to bright redness, the carbon is converted into carbonic anhydride at the expense of a portion of the oxygen of the cupric oxide, while the nitrogen is liberated, partly in the free state and partly in the forms of its lower oxides, the quantity of these latter being reduced as much as possible by causing them to pass over the surface of red-hot metallic copper, which abstracts the oxygen and leaves the nitrogen free. In other words, the substances are obtained and estimated by what is known to chemists as a "combustion."

As far back as 1864 an unsuccessful attempt had been made by Weltzien to apply this process to the estimation of carbon in water. The failure was due to the very minute quantities available for estimation, and to the fact that the water was rendered acid with sulphuric acid before evaporation, a proceeding which directly tended to vitiate the results, even had no other obstacle intervened, as the acid gradually concentrated during evaporation, ultimately became sufficiently strong to char and decompose much of the organic matter present.

It was not until Dr. Hermann Sprengel had placed in the hands of chemists a new and powerful means of research in the shape of the admirable air-pump which bears his name, that it was possible to estimate directly the minute amounts of carbon and nitrogen which water, as a rule, contains.

In March 1868 Messrs. Frankland and Armstrong published a method of water analysis which they had elaborated, after eighteen months' work at the subject.

A quantity of water proportionate to the amount of ammonia found,* and varying from one litre in the case of a town water-supply, to 100 cubic centimetres in the case of a much polluted water, is introduced into a flask, and 15 cubic centimetres of a saturated solution of sulphurous anhydride are added, and the water boiled briskly for three minutes; the water is then removed from the source of heat, and a portion introduced into a hemispherical lipless glass dish of about 100 to 120 cubic centimetres capacity; this is placed on a steam bath, and to the first dishful two or three drops of a moderately strong solution of ferric chloride are added. Should the water leave but a small solid residue, or contain little calcic carbonate, a few drops of a solution of sodic sulphite should also be added. The dish is then covered with a cap of filtering paper stretched over a ring of cane, and the evaporation continued, the rest of the water being kept warm in the flask, and added from time to time to the dish. The laboratory in which this operation is performed should be kept free from dust, and no ammonia should ever be allowed in it.

The rationale of the process so far is very simple, and is as follows:—The first boiling with sulphurous acid expels the free carbonic acid in the water, and also any that

* If the ammonia be less than 0.1 part per 100,000, 1 litre should be used; if more than 1.0, a hundred cubic centimetres or less. (See Sutton's "Volumetric Analysis," J. A. Churchill, New Burlington Street, 2nd Edition, 1871, pp. 246-295.)

* See NATURE, vol. vi. p. 104.

may exist in combination as calcic carbonate, and during the evaporation the remaining sulphurous acid reduces and expels the nitrous and nitric acids present, in which the ferric chloride greatly helps it; the sulphuric acid which is thus formed is neutralised by the calcic sulphite (formed during the preliminary expulsion of carbonic acid) with liberation of fresh sulphurous acid, or should no calcic salt be present, the sodic sulphite is added to effect this.

As soon as the whole of the water is evaporated, the residue is carefully detached from the dish by means of a flexible steel spatula, and thoroughly mixed with some fine cupric oxide; it is then introduced into a stout piece of combustion tube about 430 millimetres long, one end of which has been closed, after having been very carefully cleansed, and which has about 30 millimetres of its length filled up with coarsely granulated cupric oxide.* After the mixed residue and cupric oxide have been introduced, the tube is filled up to within 100 millimetres of the open end with granular cupric oxide; a tightly-rolled cylinder of copper gauze covered with sheet copper, and which has been recently ignited and cooled in a current of hydrogen, is then put in, lastly a few millimetres more of granular cupric oxide, and the tube is then drawn out in the blowpipe flame, put into a combustion furnace, connected with a Sprengel pump, and, while the anterior part of the tube is being heated to redness, thoroughly exhausted of air. The pump is then stopped, and the heat gradually carried backwards until the whole of the combustion tube has been heated to redness. Any gas which may come off is collected from the bottom of the Sprengel pump over mercury, and as soon as the gas ceases to be evolved, the furnace is allowed to cool slightly, and the tube again exhausted. The gas pumped off is transferred to an apparatus for the analysis of gases, and measured, after the absence of sulphurous anhydride has been insured by the introduction into the gas of a drop of a solution of dipotassic dichromate. The carbonic anhydride is then absorbed by potassic hydrate, and the gas again measured, the difference being the carbonic anhydride. To the residual gas a minute bubble of oxygen is added to decompose the nitric oxide, should any be present, and after the excess of oxygen has been absorbed by pyrogallic acid, the gas again measured consists of nitrogen; to this half the difference between the two last readings is added, as this represents the nitrogen which had existed as nitric oxide, and the result is the total nitrogen.

All the above data are reduced to measures of weight by the use of the formula. $\text{Log. } \frac{.0012562}{(1 + .00367t)760}$ which gives the weight of cubic centimetres of nitrogen in grams. This table of logarithms is carried out for each tenth of a degree from 0° to 30°C.

To those uninitiated in gas analysis, the above may sound very complicated; but in practice it is found extremely simple. The whole analysis, including the calculations, can easily be carried out in half an hour, and the combustion itself need not occupy more, as a rule, than forty-five minutes.

The value of the above process is at once perceived when it is remembered that by it 0.0000005 gram. carbon and 0.0000001 gram. nitrogen are distinctly measurable quantities. The methods of analysis involving the use of gasometric measurements are by very far the most accurate in the whole range of a science whose very foundations rest on the possibility of accurately weighing and measuring varying quantities. The great capabilities of this method of inquiry have received a splendid demonstration in the researches of Sir Benjamin Brodie on Ozone; and Profs. Williamson and Russell, recognising the peculiar excellence of these methods, have endeavoured with considerable success to make them applicable

to a more extended range of work, in connection with which it will only be necessary to remind the reader of the careful determinations of the atomic weights of cobalt and nickel made by the latter chemist.

Notwithstanding these advantages, the application of this method to the determination of the organic constituents of water has encountered the most strenuous opposition in many quarters.

But until a more absolutely certain method of determining the quantities of carbon and nitrogen shall have proved Frankland and Armstrong's process to be in error, it would, indeed, be the height of folly to adopt in its place a method which, like the Albumenoid process, only professes to give a fraction of the nitrogen present (and has absolutely failed to prove that it even gives any known fraction whatever); while it does not even attempt to estimate the carbon at all. Again, over 60 per cent. of the errors given by Frankland and Armstrong in their paper are minus errors, and thus directly tend to favour the Albumenoid process when analysis of waters by the two methods are compared; for the Albumenoid process almost invariably gives less quantities of ammonia than Frankland and Armstrong's does of nitrogen. It must be borne in mind that these absolute errors are almost certainly due to errors in weighing the small quantities of substances used to test the process, quantities so small that they are admitted by the objectors to be only about one-tenth of those usually used in organic analysis.

But in the case of water no weighing at all occurs. A measured quantity of water is taken, and the quantity of carbon and nitrogen which happen to exist in that measure is ascertained, whether it be small or great.

Again, it has been urged that ammonia is lost during the evaporation. This was found to be the case; but it was a difficulty only requiring to be known in order to be remedied. Accordingly, solution of salts of ammonia made acid with sulphurous acid in one case, and with metaphosphoric acid in the other (the last acid replaces the first when sewage is operated on), were evaporated and the nitrogen determined, and from the loss found two tables* constructed, in which each alternate term was an absolute determination, and the intermediate ones calculations. The wonderful constancy with which the numbers alter for each strength of solution shows how accurate the determinations must have been in order to obtain them.

Another valuable proof of the trustworthiness of a process is to be found in the degree of agreement existing between duplicate determinations made with it; and when the process is examined in this way it certainly passes the test in the most satisfactory manner, and the following examples will show how well duplicate determinations agree with each other:—

		Parts per 100,000.	
		Organic Carbon	Organic Nitrogen.
Grand Junction Water Company	. . . 1	.185	.030
" " "	. . . 2	.172	.030
East London	" " . . . 1	.157	.026
" " "	" " . . . 2	.148	.030
New River	" " . . . 1	.239	.042
" " "	" " . . . 2	.231	.042
The Don at Alford	 1	.115	.024
" " "	 2	.112	.026
Lady Well Spring (Dundee)	 1	.029	.035
" " "	" " . . . 2	.023	.033

Indeed, the numbers given in the Registrar-General's monthly reports exhibit so remarkable an agreement among themselves that any unprejudiced judge must admit the accuracy of the method by which they were obtained. We shall consider the remainder of the subject in a concluding article.

* Made by igniting and oxidising short pieces of copper wire; it can be obtained from dealers in chemicals.

* See Sutton's "Volumetric Analysis," p. 276, 2nd Edition.